Merrimack River Basin Flood Control

DEFINITE PROJECT REPORT

for

NASHUA, NEW HAMPSHIRE

LOCAL PROTECTION

Corps of Engineers, U. S. Army

U. S. Engineer Office Boston, Massachusetts

July 1944
Revised October 1944

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July 1944
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WAR DEPARTMENT
United States Engineer Office
3d Floor, Park Square Bldg.
31 St. James Avenue
Boston 16, Mass.

15 July 1944
Revised October 1944

Subject: Definite Project Report for Nashua, New Hampshire, Local Protection.

To: The Chief of Engineers, U. S. Army, Washington, D. C., Through the Division Engineer, New England Division, Boston, Massachusetts.

1. Project Authority.- The project for local protection at Nashua, New Hampshire, as described herein is proposed as part of the comprehensive plan for flood control reservoirs and related flood contol works for the Merrimack River Basin authorized by the Flood Control Acts approved 22 June 1936 and 28 June 1938. The Flood Control Act of 1938 provides that "The project for flood control in the Merrimack River Basin as authorized by the Flood Control Act approved 22 June 1936, is modified to provide, in addition to the construction of the system of flood control reservoirs, related flood control works which may be found justified by the Chief of Engineers."

2. Previous Investigations.- The investigations and studies upon which the authorized project for the Merrimack River Basin is based are described in House Document No. 689, 75th Congress, 3d Session.

3. Location and Description of Area Affected.-

a. General.- The proposed project is located on the right banks of the Nashua and Merrimack Rivers at their confluence in the City of Nashua, New Hampshire. The site is 55 miles above the mouth of the Merrimack River; 35 miles northwest of Boston, Massachusetts; 32 miles south of Concord, New Hampshire, and 64 miles downstream and south of the completed Franklin Falls Dam on the Pemigewassett River. The area to be protected consists of approximately 70 acres that are developed extensively by industrial establishments and residences. The industries, which are quite diversified, consist of a lumber mill and manufacturing plants concerned chiefly in the production of cement-asbestos products, textile machinery, refrigerators, plumbing supplies and furniture. Nashua is an important junction of the Boston and Maine Railroad and the area to be protected by the proposed project includes the main line tracks, the railroad station, many spurs and storage yards. (See Plate 4.)

b. Flood Situation.- The greatest flood of record occurred in March 1936, when the area to be protected by the proposed project was flooded to depths ranging from 10 to 17 feet and caused total losses, direct and indirect, of nearly a million dollars. (See Plate 2.) The second largest flood of record occurred in September 1938 and again the area was inundated to depths varying from 5 to 8 feet. The average annual flood losses for the area have been computed to be approximately $20,000 without reservoir control.

c. Related Flood Control Projects.- The comprehensive plan for flood control projects and its present status are illustrated on Plate 1. Two reservoirs have been completed: (1) Franklin Falls, controlling the Pemigewassett River, the principal tributary of the Merrimack River; and (2) Blackwater Reservoir on the Blackwater River, a tributary of the Contoocook River. Other proposed reservoirs for controlling the Contoocook River are Mountain Brook, West Peterboro, Bennington and Beards Brook. The effects of these reservoirs, both existing and proposed, have been considered in determining grades for the dike to protect the inundated areas in Nashua. Local protection works, consisting of flood walls, dikes, and channel improvements have also been completed at Fitchburg, Lowell and Haverhill, Massachusetts. Similar local protective measures have been proposed for south Lawrence and North Andover, Massachusetts, on the Shawsheen River, and at west Lawrence on the Merrimack River.

4. Definite Project Plan.-

a. Work Proposed.- The area to be protected and the location of the proposed work are shown on Plates 4 and 5. It is proposed to construct approximately 3100 feet of dike and 230 feet of concrete wall starting at the Boston and Maine Railroad bridge which spans the Nashua River, extending along the south bank of the Nashua River and the west bank of the Merrimack River and continuing to high ground adjoining the railroad yard. A pumping station is to be provided for discharging sewage and drainage during the periods of high river stages. Sewage and drainage interceptors are necessary for diverting some of the existing flow to the proposed site of the pumping station. A waste disposal outfall from the Johns Manville Company manufacturing plant is to be gated to prevent backwater.

b. Design Flood.- The March 1936 flood, the maximum flood of record for the Merrimack River, had a peak flow of approximately 165,000 c.f.s. which greatly exceeded all previous discharges of record for the Merrimack River at Nashua. The flood of second magnitude occurred in September 1938 with a peak discharge of approximately 120,000 c.f.s. Similar to the design criteria used for other local protection projects, the maximum flood of record, as reduced by the comprehensive reservoir system has been selected as the design flood. Maximum river stages of record and their frequency, both uncontrolled and as affected by the proposed reservoir system, are shown on Plates 8 and 9 with the grade established for the top of the earth dike and concrete wall. These grades are summarized as follows:

Maximum recorded stage of 1936 flood	127.5 (ft.above M.S.L.)
Maximum computed stage of 1936 flood reduced by reservoirs	116.4 (ft.above M.S.L.)
Elevation of top of proposed dike	120.0 (ft.above M.S.L.)
Freeboard	3.6 ft.

It is believed that this freeboard is sufficient allowance for (1) wave action, (2) degree of accuracy in reach-routing from the headwater tributaries to Nashua, and (3) to provide effective protection for the design flood until such time as the comprehensive reservoir system is completed.

5. Hydrology.- A hydrological study has been made of the drainage area that would be affected by the construction of the proposed dikes. This area is controlled by the existing combination sewerage and drainage system that serves 615 acres of the developed section of Nashua. (See Plates 3 and 7.) The principal outfalls from this system discharge into the Merrimack River and are located near the East Hollis Street Bridge and at the end of Crown Street. The main trunk sewer is an oval-shaped brick conduit, 54-inches in height, which extends 8,000 feet along East Hollis Street. Several overflow outlets discharging direct to the Nashua River are installed to increase the discharge capacity of the sewerage system. The sewers, including these overflow outlets, can discharge a total of approximately 200 c.f.s. which is adequate for a storm of less than a two-year frequency, based on storm run-off calculations. The computed discharge capacity of the outfalls in the immediate area to be affected by the proposed construction is 120 c.f.s. It is proposed to intercept the flow from the different outfalls and pipe the flow to the site of the proposed pumping station adjacent to the East Hollis Street Bridge. Pumps will be provided with sufficient capacity to pump the maximum inflow against a head produced by the peak flood stage. The complete hydrological analysis of the drainage basin is included in Appendix "A".

6. Engineering Design.-

a. Surveys.- A topographical survey has been made of the perimeter area to determine the design and the required scope of the proposed dikes and flood walls. Detailed information was obtained also on all sewer and drain outfalls discharging within the limits of this survey. Several years ago a preliminary investigation of the site was made, utilizing an enlarged aerial photograph as a plane-table sheet to obtain topography and sewer outlets for the portions of the city bordering on the Nashua and Merrimack Rivers. The locations of buildings, railroads, streets and wooded areas were traced from the enlarged aerial photographs. The drainage area data applicable to the project, including complete information relative to the existing sewerage and drainage system were obtained in the Engineering Department at the Nashua City Hall with the cooperation of the City Engineer.

b. Foundation Explorations.- The foundation areas of the proposed dikes and retaining walls were explored by two drill holes, two auger borings and one test trench. Overburden exposures were inspected and local residents questioned regarding soil conditions. The locations and logs of explorations are shown on Plates 5 and 6. The banks of the Nashua and Merrimack Rivers on which the dike and wall are located, are approximately 18 feet above the normal river level. The faces of the river banks have a slope varying between 1 on 1 and 1 on 2. Rubbish, ashes, and miscellaneous fill have been dumped over limited areas on the faces of the river banks to a depth probably not exceeding 5 feet measured perpendicular to the slope. The ground surface at the top of the river banks slopes away from the river. The area upon which the dike is located and the area protected by the dike consists of a glacial fluvial deposit of sands and gravels to undetermined depths believed to be greater than 100 feet. The south end of the earth dike abuts into an old fill consisting largely of ashes. Bedrock outcrops are visible on the east side of the Merrimack River at the abutment of the East Hollis Street Bridge. The coefficients of permeability of the natural deposits as determined by tests upon remoulded samples vary generally between 10^{-4} and 10^{-6} cm. per sec. with thin lenses and strata ordinarily at depths greater than 15 feet below the dike foundation whose coefficients of permeability are 10^{-3} cm. per sec.

c. Description of Dikes and Walls.- The protective structures, shown on Plates 5 and 6, consist of approximately 3100 linear feet of earth dike and approximately 230 feet of concrete wall. The dike and wall will start at the Boston and Maine Railroad bridge which spans the Nashua River, will extend easterly along the top of the natural bank of the Nashua River to the Merrimack River, and continue southerly along the west bank of the Merrimack River to high ground just south of Crown Street. A low dike will extend from the southern end of this high ground westerly to the Boston and Maine Railroad tracks. The dike will consist of a compacted impervious fill, with a top width of 10 feet, a 1 on 2 slope on the land side and a 1 on 2-1/2 slope on the river side. The entire dike will be covered with 6-inches of seeded topsoil. A sand and gravel filter will be constructed at the toe of the slope on the land side for protection against seepage. The height of the dike with top at elevation 120 averages about 6 to 8 feet with a maximum height of approximately 14 feet. Due to space limitations adjacent to a storage warehouse along the bank of the Nashua River, it is proposed to construct a concrete wall with a foundation and cut-off of steel sheet piling. A removable bulkhead which can be stored in the nearby pumping station will be provided for damming the East Hollis Street approach to the Merrimack River bridge during flood stages. The earth dike will be terminated by concrete retaining walls on both sides of East Hollis Street. The low dike on the south end of the site will be approximately 400 feet long and approximately 3 feet high. Although this dike is not required for the design flood, it will provide protection for flood stages up to Elevation 120.0 which is comparable with other sections of the project. It will be necessary also under this extreme flood stage condition to construct a small sand-bag dike across the railroad tracks for complete protection.

d. Sewerage and Drainage Interceptors.- It is planned to intercept the discharge from the various outfalls and catchbasins (see Paragraph 5) and pipe the flow to the proposed pumping station near East Hollis Street Bridge. These interceptors and outfall involve the installation of approximately 1,130 feet of 8-inch tile drain, 270 feet of 12-inch pipe, 530 feet of 15-inch pipe, 690 feet of 36-inch pipe, 190 feet of 54-inch pipe, 2 catchbasins and 8 manholes or junction chambers. The interceptors will be laid on a minimum slope of 0.0050 to provide adequate velocity for the normal daily sewage discharge. This slope also will insure full utilization of the pipe capacity during periods of storm runoff.

e. Pumping Station.- The locations of the existing sewer outfalls control the selection of the most advantageous site for the pumping station. The areas adjacent to the outfalls at East Hollis Street and Crown Street are both satisfactory locations for the pumping station. The selected site near East Hollis Street, however, allows the use of a 36-inch interceptor instead of a 54-inch which would have to be specified if the pumping station were located at the end of Crown Street. A diagrammatic and floor plan layout of the pumping station is shown on Plate 6. All the sewage and drainage from the area, with the exception of that which is diverted by overflow outlets, will discharge by gravity through a conduit in the pumping station to the 54-inch outfall. During flood stages the discharge through the gravity conduit will be diverted through the pumping station by means of control gates, and the sewage and drainage will be pumped against the head produced by the flood stage. A 24-inch return line controlled by a gate valve operated from the pump room floor will be installed to permit the use of constant speed electric motor-driven pumps. The pumping station will be constructed as part of the dike to reduce the angle of flow in the 54-inch interceptor.

f. Pumps.- The characteristics and cost of various types of pumps have been considered and studied in order to satisfy the pumping requirements outlined in Paragraph 9 of Appendix "A". It is desirable to install pumps with a wide range of operating flexibility to meet the anticipated variable inflows from sewage and drainage which may range from 2 or 3 c.f.s. to 120 c.f.s., the capacity of the sewerage system and proposed catchbasins. As a result of this study, it is proposed to provide pumps of the following capacity and power units:

1 - 10 c.f.s. non-clogging Centrifugal Pump with dual electric motor and gasoline engine drive.
2 - 55 c.f.s. fixed blade propeller pumps with constant speed electric motors.

Electric motors are selected in lieu of gasoline engines due to the reduced initial cost of the equipment installation and the availability of electric power adjacent to the site. The 24-inch return line described in paragraph 6e will permit flexibility in operation by the use of constant speed electric motors. This procedure will, undoubtedly, sacrifice some of the pump efficiency, but, because of the infrequent use of the pumps, it is believed that flexibility of operation to satisfy the many possible conditions of sewage and storm run-off is a more essential criteria than pump efficiency and economy of operation. Consideration has been given to the possibility of using adjustable blade propeller pumps and to variable speed range in pumping capacity but it was concluded that due to greater cost, and the additional mechanism to be maintained in operating condition by the municipality, these types were not warranted. The local power company has consented to waive the usual stand-by charge based on the rated capacity of electric motors. A nominal monthly demand charge plus charge for actual power usage will be in effect. The resulting annual operating costs of electric motor driven pumps will be practically the same as for costs of gasoline operated pumps. The total annual cost of project including amortization is less by using electrically operated pumps. It has been determined that electric power at this location is very reliable but to allow for the remote possibility of electric power failure, the 10 c.f.s. centrifugal pump which has sufficient capacity to handle the run-off from a small rainfall in addition to the sanitary sewage will have an auxiliary gasoline engine power unit.

7. Cost Estimate.- The estimated cost of the project for which Federal funds are required is summarized as follows:

Dikes and Concrete Walls	$ 56,900.
Sewer Interceptors	21,200.*
Pumping Station	95,000.
Control Manhole	500.
	$173,600.
Engineering, Inspection, Overhead and Contingencies (25%)	43,400.
Total Estimated Cost to Federal Government .	$217,000.

*Full cost of interceptors is allocated to the Federal Government, inasmuch as these proposed interceptors eliminate the construction of another pumping station.

(For detailed analysis of Cost Estimate, see Appendix "B")

8. Benefits of Project.-

a. Methods of Analysis.- Reference is made to Section "B", Data for Economic Justification," in "Appendix to Accompany Survey Report for Navigation, Flood Control, and Water Power, Merrimack River, Massachusetts and New Hampshire," submitted by this office, dated 1 April 1940. Section "B" describes in detail the methods used in the economic analysis of flood control reservoirs based on direct and indirect flood losses. The same method applies to the economic analysis of local protection projects.

b. Determination of Benefits.- The proposed local flood protection works will supplement the effectiveness of flood protection provided at the damage centers by the upstream reservoirs and will increase the total benefits accruing to the comprehensive flood control program. The additional benefits resulting from the local protection projects have been evaluated and totalled with the benefits secured from the balance of the comprehensive flood control program to determine the economic justification for the proposed work. The proposed dikes and walls have been found to provide the most economical means of supplemental flood protection for the City of Nashua. In addition to providing protection from floods, it is believed that the proposed project will be very beneficial to the general welfare of the community by promoting development of the low areas and enhancing property values. The costs and benefits involved in the comprehensive flood control program are summarized in the following tabulation:

Summary of Benefits and Costs

(1) Construction Costs.-

(a) Local protection projects:	
Nashua	$ 217,000.
Other Projects*	1,091,150.
(b) Flood Control Reservoirs** .	16,987,000.
Total Construction Costs . .	$18,295,150.

(2) Annual Carrying Charges.-

(a) Local protection projects:	
Nashua	$ 10,240.
Other projects*	53,510.
(b) Flood Control Reservoirs** .	788,970.
Total Annual Carrying Charges	$ 852,720.

(3) Total Annual Benefits.-

Based on comprehensive flood control program, including reservoirs and local protection . . . . $ 1,060,500.

(4) Ratio of Annual Benefits to Annual Carrying Charges 1.24

* Includes completed local protection project at Lowell and proposed projects at North Andover and Lawrence, Massachusetts.

** Includes completed reservoirs at Franklin Falls and Blackwater, and proposed reservoirs at Bennington, Beards Brook, West Peterboro and Mountain Brook.

9. Local Cooperation.-

a. Views of Local Interests.- The proposed project has been discussed with the officials of Nashua in order to determine the local interest of the affected community. All officials, including the Mayor, City Engineer, and members of the City Council indicated their concern over the effect of the past floods, and emphasized their desire and approval of the proposed project to eliminate further flood damage.

b. Extent of Local Cooperation Required.- In accordance with Section 3 of the Flood Control Act, approved 22 June 1936, the local municipality will be required to furnish all lands, easements, and rights-of-way necessary for the construction of the project. The estimated cost to the City of Nashua for these items is approximately $2,500.

c. Assurance of Local Cooperation.- The City of Nashua by official action of the City Council and the Mayor on 16 June 1944 have furnished the necessary assurance that the City will: (1) furnish, without cost to the United States, all lands, easements and rights-of-way necessary for the project; (2) hold and save the United States free from all claims for damage due to the work; and (3) maintain and operate the project without expense to the United States, in accordance with regulations prescribed by the Secretary of War. A photostat copy of the resolution adopted by the City of Nashua is attached as Appendix "D".

10. Time Required for Construction.- It is estimated that the proposed project can be completed in one construction season.

11. Recommendation.- It is recommended that the local flood protection works proposed herein, at an estimated cost to the United States of $217,000, be selected as a definite project to supplement the comprehensive plan for reservoirs and related flood control works for the Merrimack River Basin as authorized by the Flood Control Acts of 1936 and 1938.

HOMER B. PETTIT
Colonel, Corps of Engineers
District Engineer

APPENDIX "A"

HYDROLOGY OF THE DRAINAGE BASIN

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APPENDIX "A"

HYDROLOGY OF THE DRAINAGE BASIN

1. Drainage Area.- Six drainage and sewerage outfalls discharge into the Nashua and Merrimack Rivers from the immediate area affected by the construction of the proposed dikes. The drainage area, served by the drainage and sewerage system, is shown on Plates 3 and 7. The area consists of a long narrow basin, approximately 2 miles in length and the width varying from 1500 to 3000 feet. The total area is approximately 615 acres, or nearly one square mile. The area extends through the industrial and business sections of the city, with the outlying portions including residential developments, as may be seen on the aerial photograph (Plate No. 3). In the longitudinal direction (West to East), the basin slopes gradually towards the Merrimack River with an average slope of about 6 feet per 1000 feet. The grade is variable but approximately level in the transverse direction (North-South). In some places the topography slopes towards the Nashua River and in other locations, the ground pitches towards East Hollis Street where the trunk sewer is installed. Except for the low area lying in the angle of the confluence of the two rivers, most of the drainage area is at elevations well above flood stages.

2. Existing Sewerage and Drainage.- The drainage area is served by a combination sanitary and storm sewer. The trunk sewer, an oval-shaped brick conduit 54-inches in height and 11.2 square feet in cross-sectional area, extends along East Hollis Street from Pine Street for a distance of 8000 feet and discharges into the Merrimack River at a point adjacent to the East Hollis Street Bridge. Smaller sewers serve the many side streets but all eventually discharge into the 54-inch sewer. The purpose of the long trunk sewer to the Merrimack River was to minimize insofar as possible the discharge of sanitary sewage into the Nashua River. Subsequent to the construction of the 54-inch sewer in 1885, the development of the city made it necessary to construct overflow outlets to the Nashua River to relieve the pressure on the main sewer during periods of intense rainfall. The principal overflow is a 36-inch pipe located in Walnut Street (Plate 7), which reduces the possibility of a surcharge head on the upper portion of the basin. In the lower portion of the basin, a 30-inch overflow is installed in Denton Street (Plate 5) to divert some of the flow in the 54-inch sewer to a 42-inch outfall in Crown Street. A 15-inch sewer in Temple Street, extending 3500 feet to the East Hollis Street sewer, evidently proved to be inadequate, for three more overflows have been installed to discharge from the Temple Street sewer directly into the Nashua River. These three outlets, however, do not have any direct effect on the main trunk sewer. The grades of all the overflows are sufficiently high to make it impossible for water to back into the sewerage system during flood stages. The computed capacity of the sewer outlets,

based on size, slope, and an "n" value of 0.015 in Kutter's formula, are as follows:

Location	Size of Outlet	Capacity
East Hollis Street	54"	80 c.f.s.
East Hollis Street	12"	2 c.f.s.
Bridge Street	18"	6 c.f.s.
Crown Street	42"	60 c.f.s.
Crown Street	10"	2 c.f.s.
Walnut Street (overflow from 54")	36"	30 c.f.s.
Temple Street (overflows)	30"	25 c.f.s.
Temple Street (overflows)	24"	15 c.f.s.
Temple Street (overflows)	18"	6 c.f.s.
Gregg Mill Drain	-	2 c.f.s.

Although the arithmetical total capacity of these outlets is 228 c.f.s., the discharge in the 42-inch sewer in Crown Street is limited by the 30-inch pipe in Denton and Crown Streets which is computed to be approximately 25 c.f.s. Based on the foregoing computations, the total discharge capacity from the sewerage system serving the drainage area of 615 acres is approximately 200 c.f.s., including the overflows to the Nashua River.

3. Industrial Waste.- A 24-inch diameter pipe discharges industrial waste from the plant of the Johns-Manville Company to the Nashua River, as indicated on the plan (Plate 5). This waste formerly was discharged into the City sewerage system and emptied into the Merrimack River. However, due to the high content of cement and asbestos in the waste that deposited within the sewers and caused high cost of maintenance, this method of disposal was stopped and the 24-inch pipe installed to discharge the waste to the nearby Nashua River. Considerable maintenance is required to remove the deposit from this line and the large size drain was installed principally to facilitate cleaning. It is estimated the maximum rate of discharge from this plant is about 0.5 c.f.s.

4. Storm Rainfall.- The rainfall intensity data prepared by David L. Yarnell, and published in the United States Department of Agriculture publication No. 204, were used for this study as there are no rainfall records for Nashua suitable for use as maximum precipitation rates for storms of comparatively short duration. Due to the narrowness and the length of this drainage basin, rainfall rates were used for 15, 30 and 45 minute durations for various frequencies in years in order to determine the condition producing the maximum run-off. The areas contributing to the run-off from the different rainfall intensities were based on the estimated times of concentration. This time for each area was approximated by estimating the average velocity of the flow from the perimeter of the area to the trunk sewer in West Hollis Street and using the computed velocity of flow from the assumed point of discharge

into the 54-inch sewer to the outfall at the Merrimack River. The mean slope of this sewer (0.006) is quite steep for its size, and the velocity of flow when discharging half full or more is nearly 8 feet per second. Consequently the time of concentration for the entire area of 615 acres is estimated to be only 45 minutes. The values of rainfall for this period were interpolated from the 30 and 60 minute curves in Yarnell's publication. The effective drainage areas applicable to the 15 and 30 minute periods of concentration were computed to be 140 and 450 acres respectively. The rainfall values used for the determination of the storm run-off are tabulated in the following paragraph.

5. Storm Run-off.- The storm run-off was based on the Rational Formula $Q = C\ I\ A$, in which

Q = Run-off in c.f.s.

C = Coefficient dependent on the soil conditions and characteristics of the topography and represents the ratio of the rate of run-off to the rate of rainfall.

I = The maximum average intensity of rainfall over the entire drainage area in inches per hour which may occur during the time of concentration.

A = Drainage area in acres.

Consideration was given to other methods of computing surface run-off such as the Burkli-Ziegler Formula and the synthetic unit hydrograph, but because of the size and characteristics of the drainage area and the lack of discharge data from the existing system, it is believed that the Rational Method is the most practical. The values of "C" were estimated from an evaluation of the type, slope, relative imperviousness of the different surfaces, and the areas of natural surface storage. It should be noted that although rather high coefficient values are ordinarily applied to the run-off from individual buildings and paved areas, the value of "C" as utilized in computing run-off from areas of this magnitude represents an estimated average ratio of the discharge rate as accumulated in the sewerage system to the rainfall intensity. Consequently, the amount of run-off which actually flows overland and discharges into the trunk sewer is dependent on the extent of the overland flow, the amount of surface storage, seepage, and whether the catchbasin inlets are properly located to intercept the surface run-off. The estimated values of "C" for the various types of development are as follows:

Densely developed business blocks	0.40
Industrial areas	0.35

Densely developed residential areas	0.30
Suburban residential areas	0.20
Cemetery	0.15
Wooded and undeveloped areas	0.10

The average values of "C" were determined by prorating the above coefficients to each section of the area as applicable based on a study of enlarged aerial photographs. The theoretical amount of storm run-off was computed from the preceding data, as follows:

Fifteen (15) minute concentration effective drainage area = 140 acres, average "C" = 0.26.

Frequency	Rainfall	Run-off
2 years	2.7 inches per hour	98 c.f.s.
5 years	3.5 inches per hour	127 c.f.s.
10 years	4.0 inches per hour	146 c.f.s.
25 years	5.0 inches per hour	182 c.f.s.

Thirty (30) minute concentration effective drainage area = 450 acres, average "C" = 0.30.

Frequency	Rainfall	Run-off
2 years	1.8 inches per hour	243 c.f.s.
5 years	2.4 inches per hour	324 c.f.s.
10 years	2.8 inches per hour	378 c.f.s.
25 years	3.6 inches per hour	486 c.f.s.

Forty-five (45) minute concentration total drainage area = 615 acres, average "C" = 0.29.

Frequency	Rainfall	Run-off
2 years	1.4 inches per hour	250 c.f.s.
5 years	1.8 inches per hour	321 c.f.s.
10 years	2.2 inches per hour	393 c.f.s.
25 years	2.8 inches per hour	500 c.f.s.

It is obvious that in respect to design considerations, the run-offs computed for the 30 and 45 minute concentrations are practically identical. The existing sewerage system is adequate for a storm with a frequency of less than 2 years, based on the foregoing computations and using the computed outlet discharge capacity of approximately 200 c.f.s. Storms of greater intensity will tend to produce a surcharged sewerage system with pondage beginning to collect at low points.

6. Sanitary Sewage Flow.- The maximum rate of sewage flow from the entire area was based on the following data and discharge assumptions:

a. Population = 15,000 (Based on census records for wards.)
b. Daily Discharge = 100 gallons per capita
c. Load Factor (Ratio of maximum to average flow) = 3.

The average sanitary sewage flow based on these assumptions was computed to be 1.7 c.f.s. with a maximum rate of flow of about 5.2 c.f.s.

7. Seepage.- It is estimated that the rate of seepage will be about 0.0001 c.f.s. per linear foot per 10 feet of head, based on the subsurface exploration at the site and an analysis of the material encountered. The total rate of seepage for the entire length will be approximately 0.25 c.f.s. Toe drains are proposed for the higher sections of the dike but are believed unnecessary for the lower sections due to the small amount of seepage.

8. Capacity of Proposed Interceptors.- It is planned to intercept the drainage from the Gregg Mills and the Crown Street outlets and pipe the sewage and storm run-off to the proposed pumping station near the East Hollis Street Bridge. The 15-inch interceptor from the yard drainage for the Gregg Mills will have a discharge capacity of 2 c.f.s. which is adequate for the drainage area that it serves. It is proposed to provide a 36-inch pipe to intercept the flow in the 42-inch sewer in Crown Street since the flow in the 42-inch pipe is limited by the capacity of the 30-inch sewer that discharges into the 42-inch sewer (see paragraph 2, Appendix "A".) Tracing back still further, it is to be noted that except for the flow in the 18-inch sewer in Arlington Street and an 18-inch sewer through the yard of the Gregg Mills, the major portion of the flow must come from the 54-inch East Hollis Street trunk sewer through the 30-inch overflow in Denton Street. Consequently, it is concluded that the 42-inch pipe is larger than necessary and that a 36-inch interceptor is adequate to intercept all flow in the 42-inch outfall plus 1.5 c.f.s. from the proposed catchbasin. The location and proposed grades for these interceptors are shown on Plate 5.

9. Pumping Requirements.- The design pumping capacity is controlled by the discharge capacity of the existing sewerage system and the proposed interceptors. It is estimated that the maximum rate of inflow to the pumping station will be 120 c.f.s., based on the computed rates of discharge and the practical limitations of the flow in the Crown Street 42-inch sewer. This rate is obtained as follows:

Location	Size	Discharge
East Hollis Street	54"	80 c.f.s.
East Hollis Street	12"	2 c.f.s.
Bridge Street	18"	6 c.f.s.
Crown Street	42"	25 c.f.s.
Crown Street	12"	2 c.f.s.
Gregg Mills Drain	15"	2 c.f.s.
2 proposed catchbasins	12"	3 c.f.s.
		120 c.f.s.

It is expected that pumping will be required approximately once every five (5) years from a frequency study of the discharges on the Merrimack River at Nashua (Plate 9). This expectancy is based on the assumption that pumping will be necessary when the river stage rises to Elevation 105, or approximately 4 to 5 feet below the lowest ground grade. The synchronization of flood stages and high intensity rainfall at Nashua is possible but very improbable. All of the major floods in the basin originate in the mountainous watersheds in the north portion of the drainage basin, due to the hydraulic characteristics of the Merrimack River. It has been determined from rainfall and discharge records that the arrival of the flood crest at Nashua follows the center of the flood-producing storm by approximately 48 hours. Hence, the flood peaks usually occur at Nashua during the clear weather that ordinarily follows the flood-producing storms. During this condition of high river stage, it will be necessary to pump only the sanitary sewage flow. It is proposed to provide one non-clogging centrifugal pump with a capacity of 10 c.f.s., which is adequate for all sanitary sewage and small rainfall occurring simultaneously with the flood stage. Two large pumps will be included for the most adverse possible condition despite the improbability of its occurrence; that is, a storm of sufficient intensity to produce maximum flow in the sewerage system simultaneous with the crest of the flood. These two pumps will have a capacity of 55 c.f.s. each against a head of the maximum river stage which will be approximately 25 feet. The total pumping capacity will be 120 c.f.s., which is the computed discharge capacity of the inflowing sewers and proposed catchbasins. Expressed in terms of inches of run-off per hour from the entire drainage area of 615 acres, the capacities of the sewers and pumps are as follows:

	c.f.s.	Inches Per Hour
Entire sewerage system, including all overflows	200	0.33
Total pumping capacity	120	.20

It is believed unnecessary to provide pumping capacity in excess of the computed capacity of inflowing sewers to the station. As previously stated, the probability of synchronized occurrence of severe rainfall and high flood stage is very remote; it is, therefore, believed further that sufficient insurance exists in the event of failure of one pumping unit. If one 55 c.f.s. pump should fail, the remaining capacity would be 65 c.f.s. or .11 inches per hour over entire 615 acres.

10. Discussion.- Consideration has been given to the desirability of decreasing the pumping requirements by diverting more of the flow from the 615 acre drainage area before it arrives in the low section where diversion is impossible. According to the City Engineer, with whom this subject was discussed, additional outlets have been contemplated by the City. Their plan is to install another outlet similar to the Walnut Street 36-inch overflow, but to flow south to Harbor Pond and Salmon Brook (Plate 7). An alternate to this scheme would be to construct an outlet at Spruce Street and discharge northerly to the Nashua River. This method has been investigated to determine the effect on the pumping capacities if all the sewage and storm run-off were diverted during periods of high river stages occurring simultaneously with a high intensity rainfall. Complete diversion during this condition would involve the construction of an underground chamber for the gate control of the respective outlets. However, the sewage and storm run-off still would have to be pumped from an area of 245 acres east of Spruce Street. The design run-off from this area, computed similarly to the tabulations in paragraph 5, Appendix "A", would be sufficient to fill the sewerage system and there would not be any advantage in reducing the pumping requirements. The storm run-off computations indicate that such a diversion is very desirable to relieve surcharge on the 54-inch trunk sewer, but it is concluded that such construction, if undertaken, would be by and at the expense of the City of Nashua instead of the Government.

APPENDIX "B"

COST ESTIMATE

Item	Quantity	Unit	Unit Cost	Cost	
1. **Dikes and Wall:**					
Stripping	3,600	C.Y.	$ 0.50	$ 1,800.	
Excavation	1,600	C.Y.	0.60	1,100.	
Compacted Impervious Fill	17,100	C.Y.	1.25	21,400.	
Backfill	100	C.Y.	0.50	100.	
Sand and Gravel	2,750	C.Y.	1.75	4,800.	
Topsoil	2,050	C.Y.	2.75	5,600.	
Seeding	2.6	Acre	375.00	1,000.	
Concrete	220	C.Y.	25.00	5,500.	
Steel Reinforcing	13,500	Lb.	0.07	900.	
Steel Sheet Piling	3,120	S.F.	2.00	6,200.	
Riprap	220	S.Y.	5.00	1,100.	
Bulkhead		L.S.		7,500.	
Cost of Dikes and Wall					$ 56,900.
2. **Sewer Interceptors:**					
8" Vitrified Clay Drain	1,130	Ft.	$ 0.75	$ 850.	
12" Sewer	270	Ft.	2.50	675.	
15" Sewer	530	Ft.	3.20	1,700.	
36" Sewer	690	Ft.	12.50	8,625.	
54" Sewer	190	Ft.	30.00	5,700.	
Outfall Headwall, etc., for 54" Sewer		L.S.		1,500.	
Manholes	3	Each	150.00	450.	
Manholes	4	Each	250.00	1,000.	
Manholes	1	Each	400.00	400.	
Catchbasins	2	Each	150.00	300.	
Cost of Sewer Interceptors					$ 21,200.
3. **Pumping Stations:**					
(a) East Hollis Street Station:					
Structure				$55,000.	
Pumps				40,000.	
(b) Control Manhole for Industrial Waste				500.	$ 95,500.
4. Subtotal					$173,600.
5. Engineering, Inspection, Overhead and Contingencies, (25%) . . .					43,400.
6. Total Cost					$217,000.

APPENDIX "C"

TABLE OF COSTS AND ANNUAL CHARGES

I.	Federal Investment:		
A.	Construction Costs of Structures (50 year life) (No interest charge for construction period of one year or less.)		$167,000.
B.	Equipment Costs (30 year life)		$ 50,000.
C.	Total Federal Investment		$217,000.
D.	Annual Federal Carrying Charges:		
	1. 3% Interest	$6,510.	
	2. Amortization, Structures (0.886%)	1,480.	
	3. Amortization, Equipment (2.102%)	1,050.	
	4. Total Federal Carrying Charges		$ 9,040.
II.	Non-Federal Investment:		
A.	Land and Easements		$ 2,500.
B.	Annual Non-Federal Carrying Charges:		
	1. 4% Interest	$ 100.	
	2. Annual Cost of Maintenance and Operation	1,100.	
	3. Total Non-Federal Carrying Charges		$ 1,200.
III.	Total Annual Carrying Charges		$ 10,240.

APPENDIX "D"

RESOLUTION

PERTAINING TO A PROPOSED FLOOD CONTROL PROJECT IN THE CITY OF NASHUA BY THE UNITED STATES GOVERNMENT UNDER THE DIRECTION OF THE SECRETARY OF WAR AND SUPERVISION OF THE CHIEF OF ENGINEERS.

CITY OF NASHUA

In the Year of Our Lord One Thousand Nine Hundred and forty-four.

RESOLVED, By the Board of Aldermen of the City of Nashua

Whereas, under the authority of Flood Control Act of 1938, approved by the President on June 28, 1938, which provides in part that "in addition to the construction of a system of flood control reservoirs, related flood control works which may be found justified by the Chief of Engineers", funds have been allotted by the Federal Government for the preparation of definite project plans for flood protection in the City of Nashua, State of New Hampshire;

Whereas, Section 3 of the Flood Control Act approved June 22, 1936, provides that "no money --- shall be expended on the construction of any project until --- responsible local agencies have given assurances satisfactory to the Secretary of War that they will, (a) provide without cost to the United States all lands, easements, and rights-of-way necessary for the construction of the project, --- (b) hold and save the United States free from damages due to the construction works, (c) maintain and operate all the works after completion in accordance with regulations prescribed by the Secretary of War;---";

Whereas, the proposed improvements at Nashua, New Hampshire, will be prosecuted under the direction of the Secretary of War and supervision of the Chief of Engineers, and

Whereas, the plans for the proposed improvements will be for the benefit principally of the inhabitants of Nashua, New Hampshire,

NOW, THEREFORE, BE IT RESOLVED, that upon approval of the Chief of Engineers of the definite project plans and the allotment of funds for the proposed works of improvement, the City of Nashua will, (a) furnish without cost to the United States all lands, easements, and rights-of-way necessary for said works. The lands, easements, and rights-of-way which said City of Nashua shall furnish shall include those needed for the sites of structures, for spoil disposal areas, for access roads, and all other rights in, upon, through or over private property which are needed by the United States in connection with the work of improvement. Maps showing the lands, easements, or rights-of-way needed for the aforesaid work will be obtained by the City of Nashua from the Unites States. Detailed property surveys and title searches necessary to acquire the land or interests therein will be performed by the City; (b) that the Mayor of the City of Nashua, New Hampshire, be and hereby is authorised to execute, acknowledge, and deliver, for and on behalf of the City of Nashua, to the United States any and all instruments which may be required by the United States in order to prosecute the proposed work of improvement, and to authorize and permit the said United States to act for and on behalf of the City of Nashua, New Hampshire, under any easements, grants or rights-of-way that have been obtained by or may be hereafter obtained by said City of Nashua in connection with said proposed improvement.

Be it further resolved that the said City of Nashua, New Hampshire, will hold and save the United States, its officers and employees, free from all claims for damages and from all liabilities due to the construction work and upon completion of the proposed flood control works the City of Nashua will accept the same and will maintain and operate them without expense to the United States in accordance with regulations prescribed by the Secretary of War.

IN THE BOARD OF ALDERMEN

First Reading	May 9, 1944
Second Reading	June 13, 1944
Passed	June 13, 1944

Attest: Irenee D. Ravenelle
City Clerk

Edward R. Benoit
President

Approved
June 16, 1944

Eugene H. Lemay
Mayor

The foregoing is a true copy of the Resolution thereon.

Attest: Irenee D. Ravenelle
Irenee D. Ravenelle,
City Clerk.

Nashua, N. H. June 16, 1944

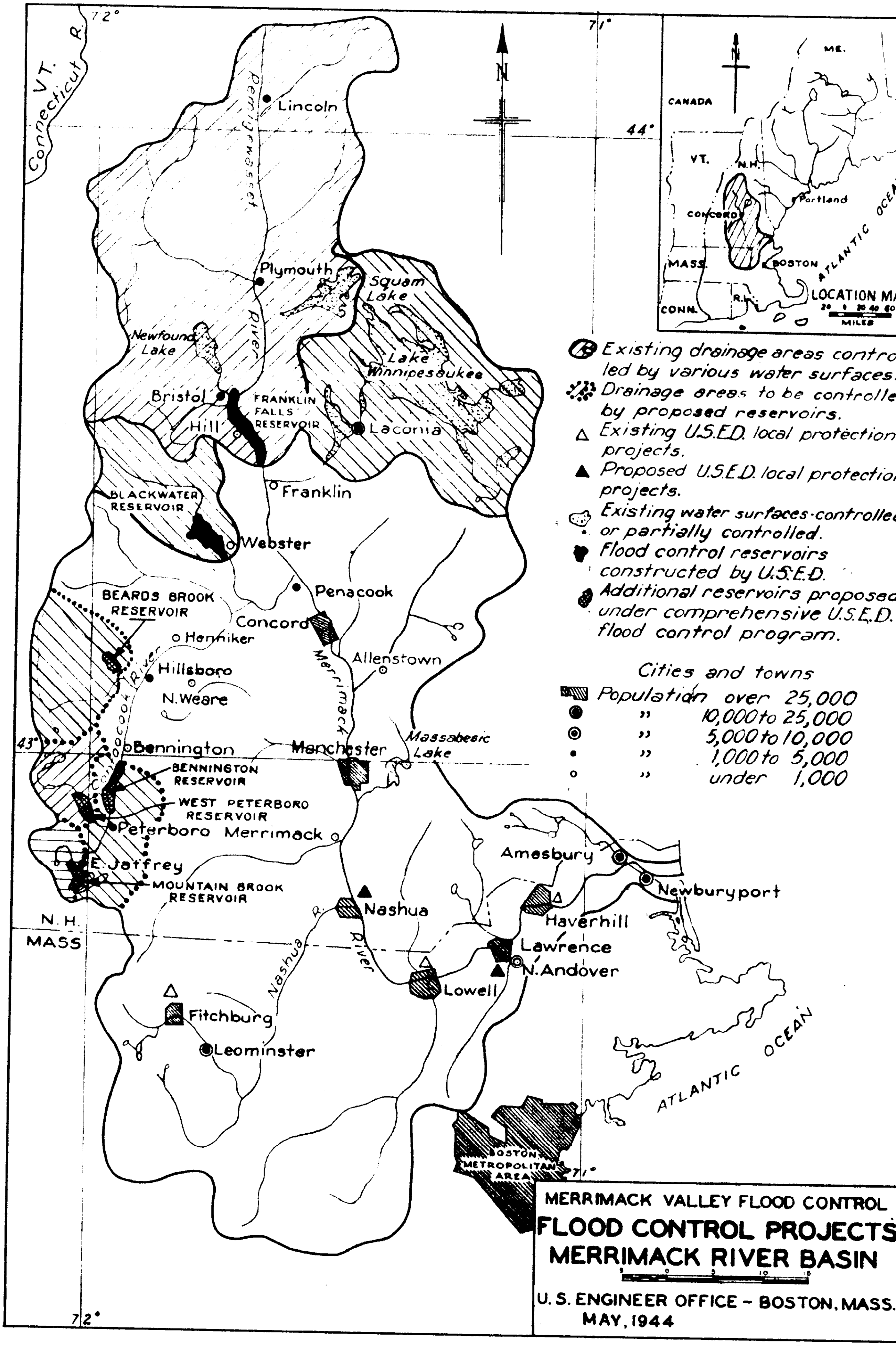
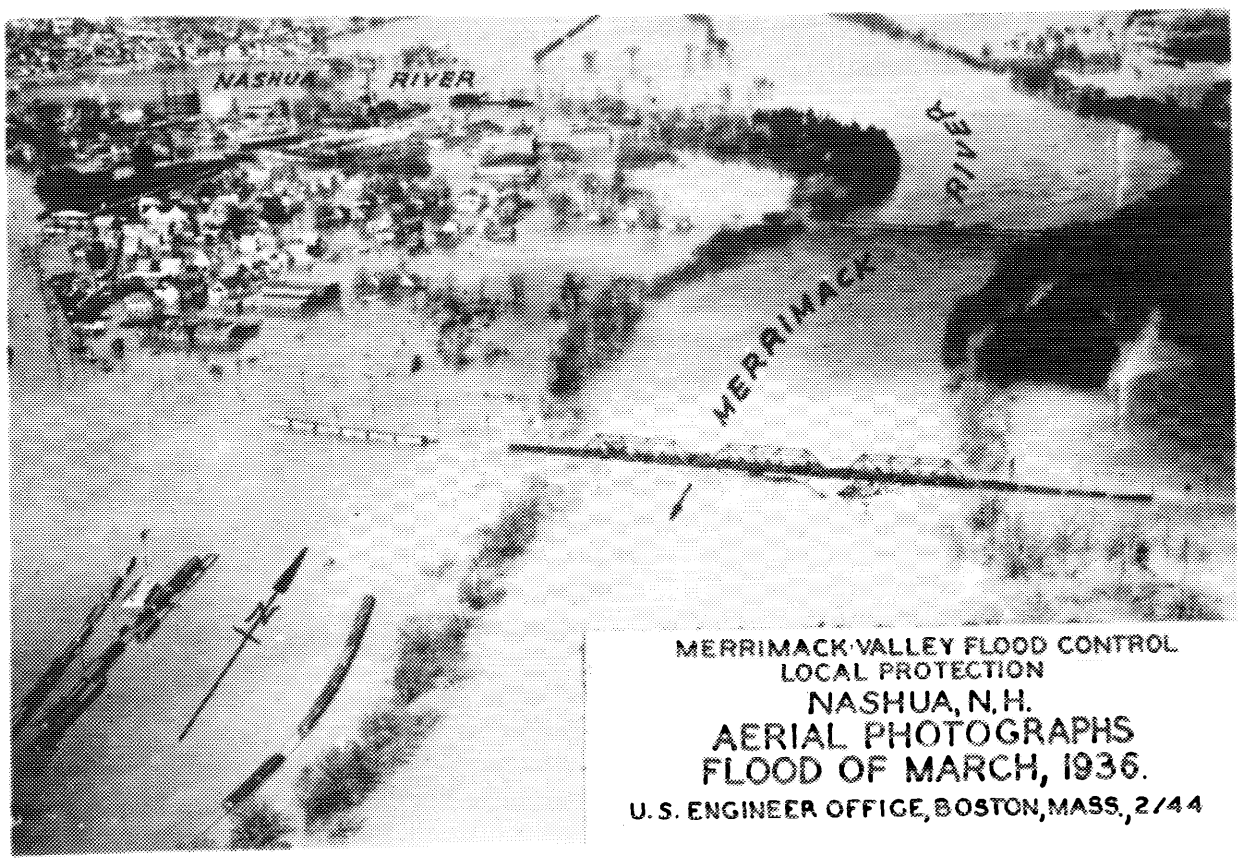

MERRIMACK VALLEY FLOOD CONTROL
FLOOD CONTROL PROJECTS
MERRIMACK RIVER BASIN
U. S. ENGINEER OFFICE – BOSTON, MASS.
MAY, 1944
Existing drainage areas controlled by various water surfaces.
Drainage areas to be controlled by proposed reservoirs.
Existing U.S.E.D. local protection projects.
Proposed U.S.E.D. local protection projects.
Existing water surfaces-controlled or partially controlled.
Flood control reservoirs constructed by U.S.E.D.
Additional reservoirs proposed under comprehensive U.S.E.D. flood control program.
Cities and towns
Population over 25,000
" 10,000 to 25,000
" 5,000 to 10,000
" 1,000 to 5,000
" under 1,000
LOCATION MAP
MILES
CANADA
ME.
VT.
N.H.
CONCORD
Portland
MASS.
BOSTON
R.I.
CONN.
ATLANTIC OCEAN
72°
71°
44°
43°
N
VT.
Connecticut R.
Lincoln
Pemigewasset River
Plymouth
Squam Lake
Newfound Lake
Lake Winnipesaukee
Bristol
Hill
FRANKLIN FALLS RESERVOIR
Laconia
Franklin
BLACKWATER RESERVOIR
Webster
Penacook
BEARDS BROOK RESERVOIR
Concord
Henniker
Allenstown
Hillsboro
N. Weare
Contoocook River
Merrimack River
Bennington
Manchester
Massabesic Lake
BENNINGTON RESERVOIR
WEST PETERBORO RESERVOIR
Peterboro
Merrimack
E. Jaffrey
MOUNTAIN BROOK RESERVOIR
Amesbury
Newburyport
Haverhill
Nashua
Nashua River
N. H.
MASS
Lawrence
N. Andover
Lowell
Fitchburg
Leominster
BOSTON METROPOLITAN AREA
ATLANTIC OCEAN

PLATE I



MERRIMACK VALLEY FLOOD CONTROL
LOCAL PROTECTION
NASHUA, N.H.
AERIAL PHOTOGRAPHS
FLOOD OF MARCH, 1936.
U. S. ENGINEER OFFICE, BOSTON, MASS., 2/44

PLATE 2

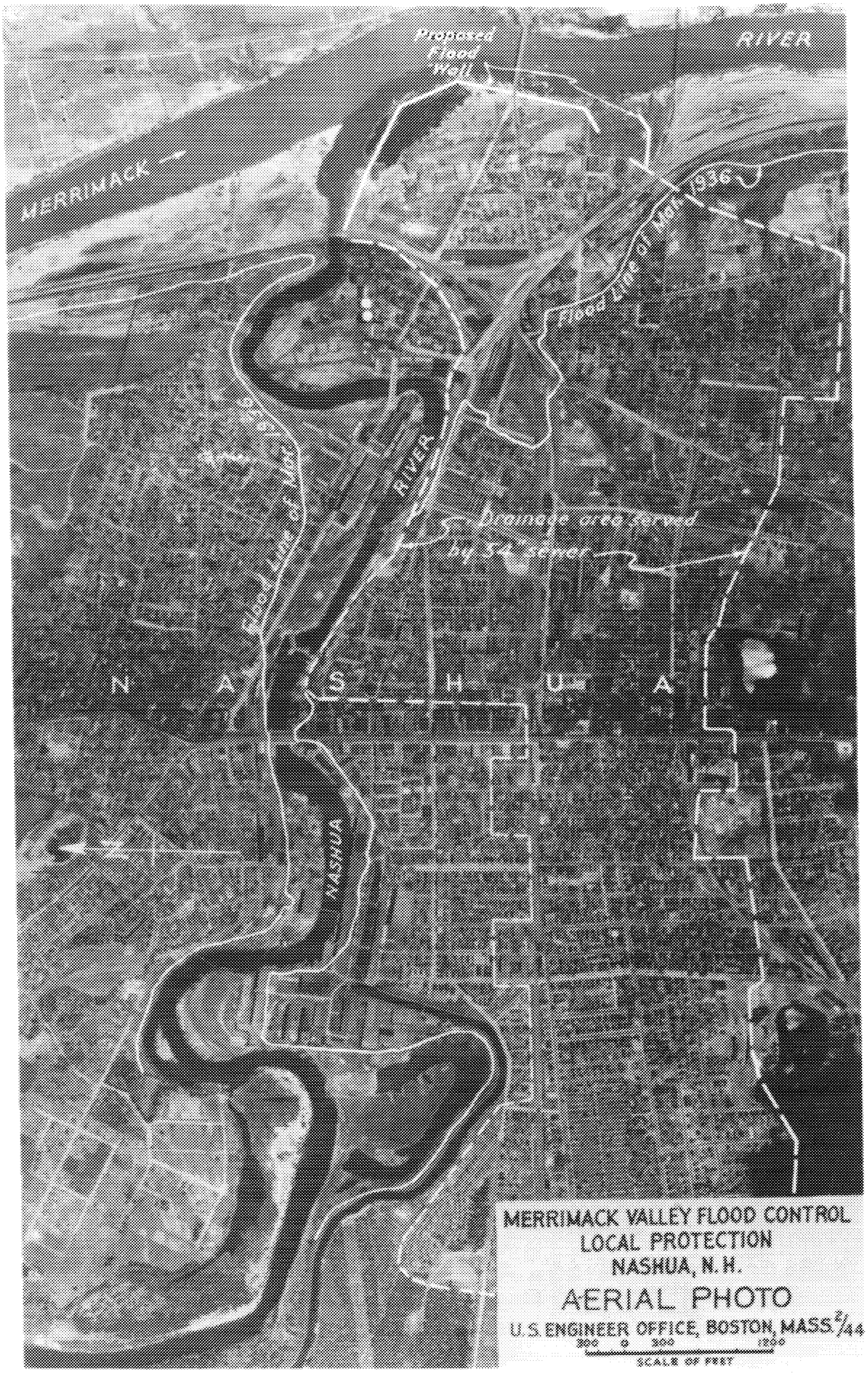

Proposed Flood Wall
MERRIMACK
RIVER
Flood Line of Mar. 1936
RIVER
Drainage area served by 54" sewer
N A S H U A
NASHUA
MERRIMACK VALLEY FLOOD CONTROL
LOCAL PROTECTION
NASHUA, N. H.
AERIAL PHOTO
U.S. ENGINEER OFFICE, BOSTON, MASS. 2/44
300 0 300 1200
SCALE OF FEET

PLATE 3

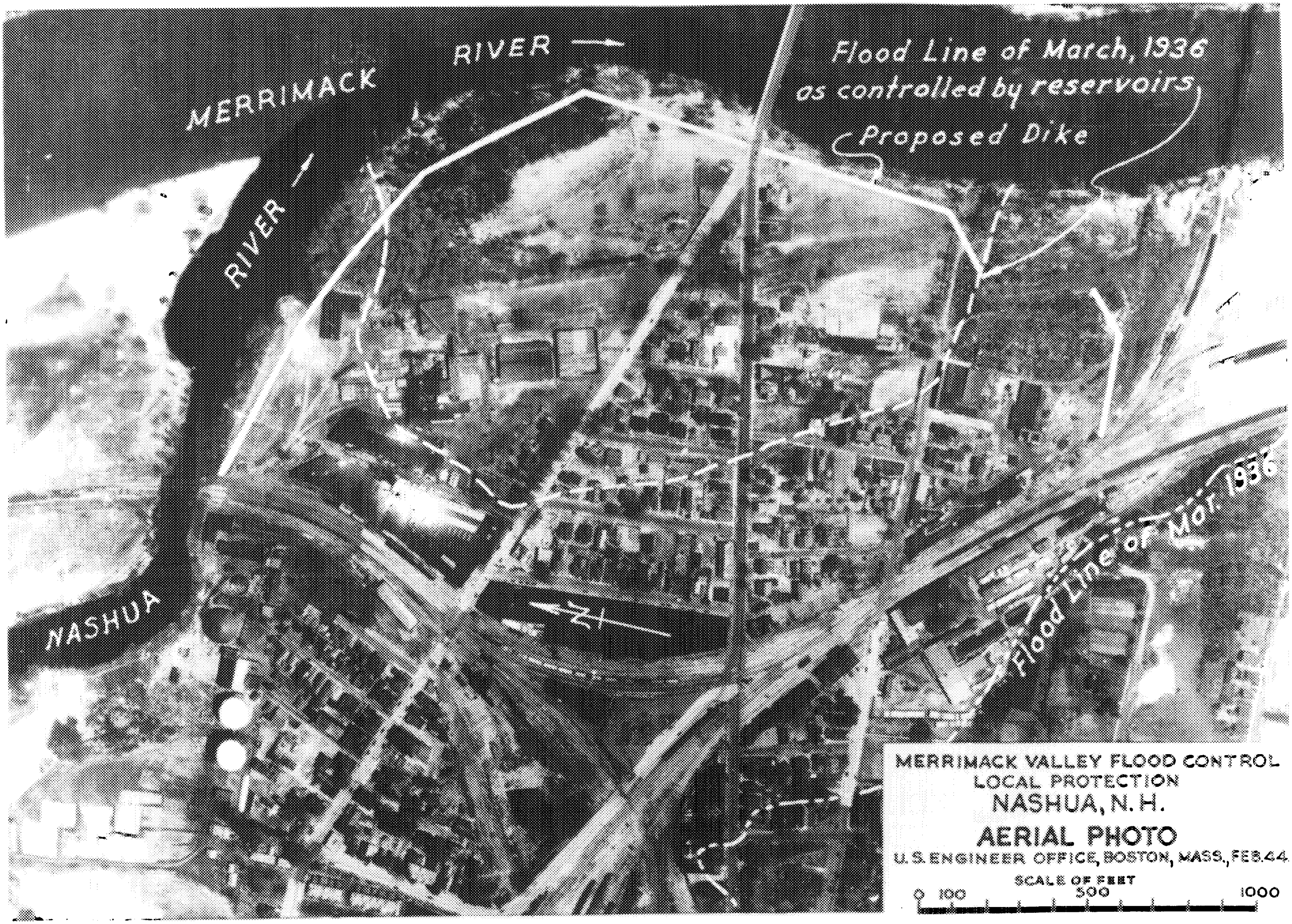
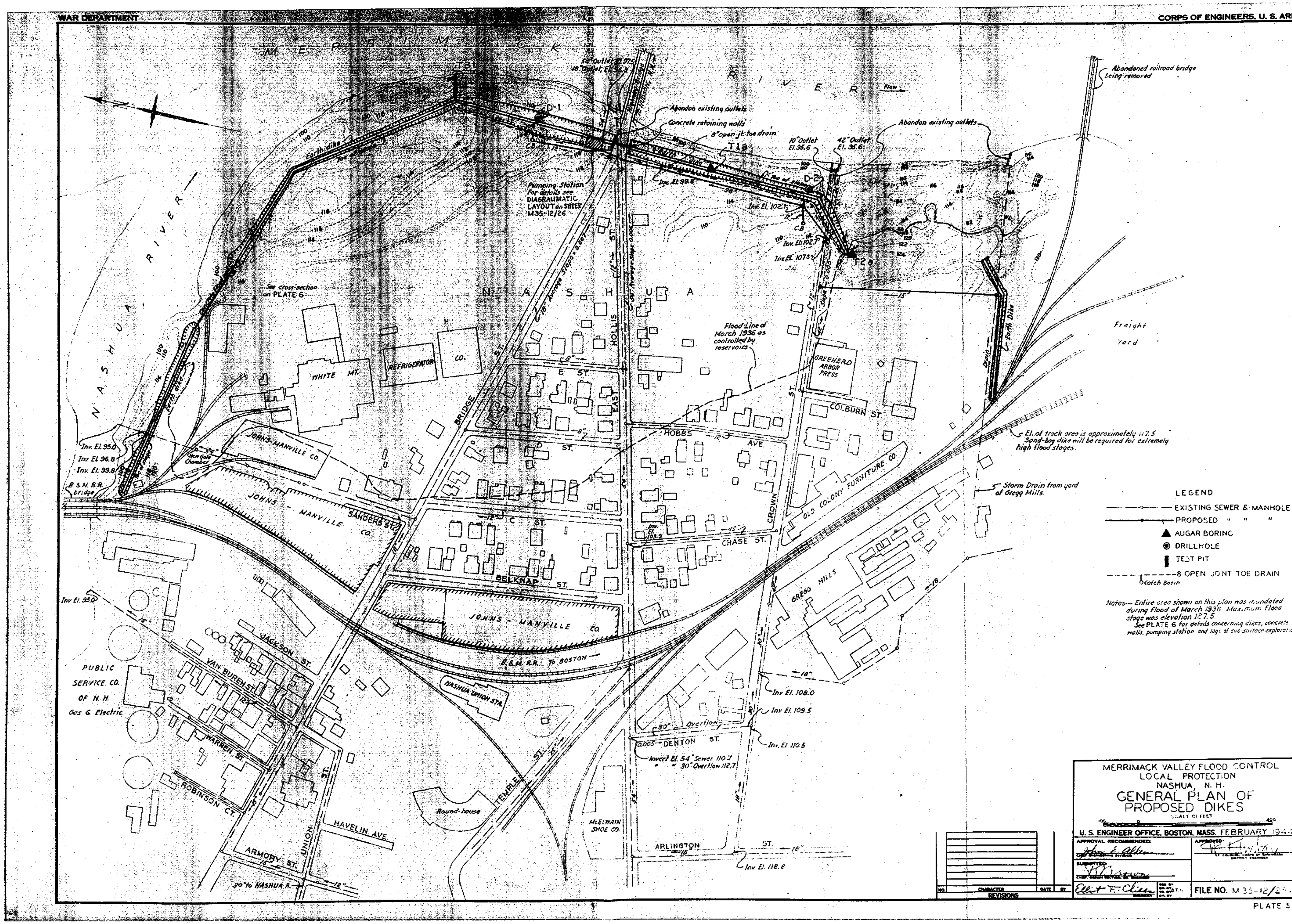
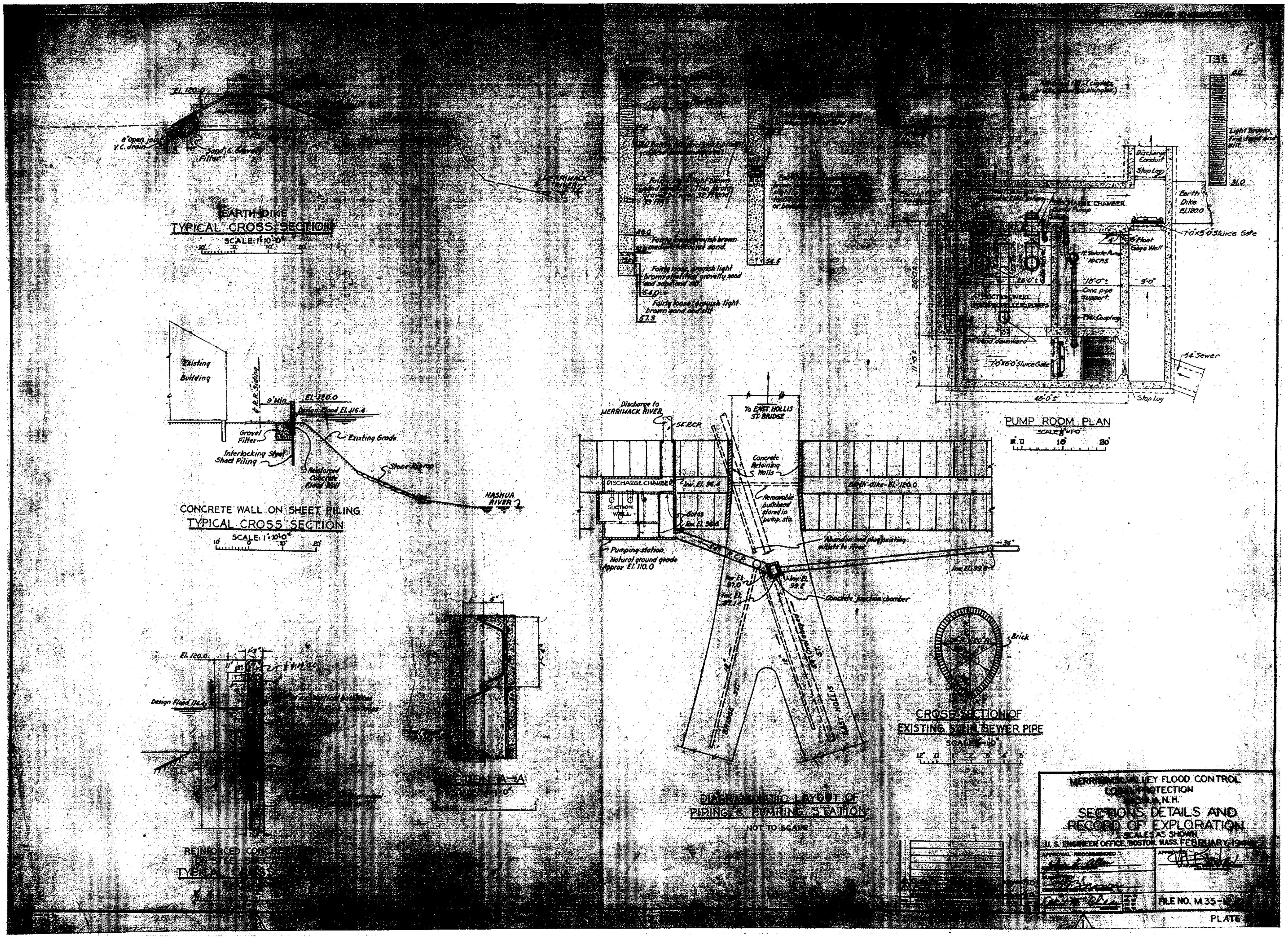

MERRIMACK RIVER
RIVER
NASHUA
Flood Line of March, 1936 as controlled by reservoirs
Proposed Dike
Flood Line of Mar. 1936
N
MERRIMACK VALLEY FLOOD CONTROL
LOCAL PROTECTION
NASHUA, N. H.
AERIAL PHOTO
U.S. ENGINEER OFFICE, BOSTON, MASS., FEB. 44
SCALE OF FEET
0 100 500 1000

PLATE 4



WAR DEPARTMENT
CORPS OF ENGINEERS, U. S. ARMY
MERRIMACK RIVER
Flow
NASHUA RIVER
NASHUA
54" Outlet El. 97.5
18" Outlet El. 96.3
Abandon existing outlets
Concrete retaining walls
8" open jt. toe drain
10" Outlet El. 95.6
42" Outlet El. 95.6
Abandoned railroad bridge being removed
Pumping Station For details see DIAGRAMMATIC LAYOUT on SHEET M35-12/26
See cross-section on PLATE 6
Earth dike
Flood Line of March 1936 as controlled by reservoirs
Freight Yard
El. of track area is approximately 117.5
Sand-bag dike will be required for extremely high flood stages
Storm Drain from yard of Gregg Mills
Inv. El. 95.0
Inv. El. 96.8
Inv. El. 99.8
B & M. R.R. bridge
WHITE MT. REFRIGERATOR CO.
JOHNS-MANVILLE CO.
GREENERD ARBOR PRESS
OLD COLONY FURNITURE CO.
GREGG MILLS
PUBLIC SERVICE CO. OF N. H. Gas & Electric
NASHUA UNION STA.
Round-house
McELWAIN SHOE CO.
B. & M. R.R. To BOSTON
BRIDGE ST.
HOLLIS ST.
EAST ST.
CROWN ST.
E ST.
D ST.
C ST.
BELKNAP ST.
SANDERS ST.
HOBBS AVE
COLBURN ST.
CHASE ST.
JACKSON ST.
VAN BUREN ST.
WARREN ST.
ROBINSON CT.
UNION ST.
HAVELIN AVE.
ARMORY ST.
TEMPLE ST.
DENTON ST.
ARLINGTON ST.
Inv. El. 108.0
Inv. El. 109.5
Inv. El. 110.5
Inv. El. 116.8
Invert El. 54" Sewer 110.7
" " 30" Overflow 112.7
30" Overflow
90" to NASHUA R.
LEGEND
EXISTING SEWER & MANHOLE
PROPOSED " "
AUGAR BORING
DRILLHOLE
TEST PIT
8" OPEN JOINT TOE DRAIN
Catch Basin
Notes:— Entire area shown on this plan was inundated during flood of March 1936. Maximum flood stage was elevation 127.5
See PLATE 6 for details concerning dikes, concrete walls, pumping station and logs of sub-surface exploration.
MERRIMACK VALLEY FLOOD CONTROL
LOCAL PROTECTION
NASHUA, N. H.
GENERAL PLAN OF
PROPOSED DIKES
SCALE OF FEET
U. S. ENGINEER OFFICE, BOSTON, MASS. FEBRUARY 1944
APPROVAL RECOMMENDED:
SUBMITTED:
APPROVED:
REVISIONS
FILE NO. M35-12/24
PLATE 5



El. 120.0
8" open joint V.C. drain
Sand & Gravel Filter
MERRIMACK RIVER
EARTH DIKE
TYPICAL CROSS SECTION
SCALE: 1"=10'-0"
Fairly loose, grayish brown sand and silt
Fairly loose, grayish light brown and sand and silt
54.0
Fairly loose, grayish light brown sand and silt
57.9
54.5
Existing Building
El. 120.0
Design Flood El. 116.4
Gravel Filter
Interlocking Steel Sheet Piling
Reinforced Concrete Flood Wall
Existing Grade
Stone Riprap
NASHUA RIVER
CONCRETE WALL ON SHEET PILING
TYPICAL CROSS SECTION
SCALE: 1"=10'-0"
T32
31.0
Light brown, fine sand and silt
Discharge Conduit
Stop Log
Earth Dike El. 120.0
7'0"x5'0" Sluice Gate
Float Gage Well
Conc. pipe support
Flex. Coupling
7'0"x6'0" Sluice Gate
54" Sewer
Stop Log
46'-0"
PUMP ROOM PLAN
SCALE: 1/8"=1'-0"
Discharge to MERRIMACK RIVER
To EAST HOLLIS ST. BRIDGE
Concrete Retaining Walls
DISCHARGE CHAMBER
SUCTION WELL
Earth dike-El. 120.0
Removable bulkhead stored in pump. sta.
Pumping station
Natural ground grade Approx. El. 110.0
Concrete junction chamber
EAST HOLLIS ST.
Brick
CROSS SECTION OF EXISTING 54 IN. SEWER PIPE
El. 120.0
Design Flood 116.4
SECTION A-A
DIAGRAMMATIC LAYOUT OF PIPING & PUMPING STATION
NOT TO SCALE
REINFORCED CONCRETE
TYPICAL CROSS SECTION
MERRIMACK VALLEY FLOOD CONTROL
LOCAL PROTECTION
NASHUA, N.H.
SECTIONS, DETAILS AND RECORD OF EXPLORATION
SCALES AS SHOWN
U. S. ENGINEER OFFICE, BOSTON, MASS. FEBRUARY
APPROVAL RECOMMENDED
APPROVED
FILE NO. M 35-
PLATE

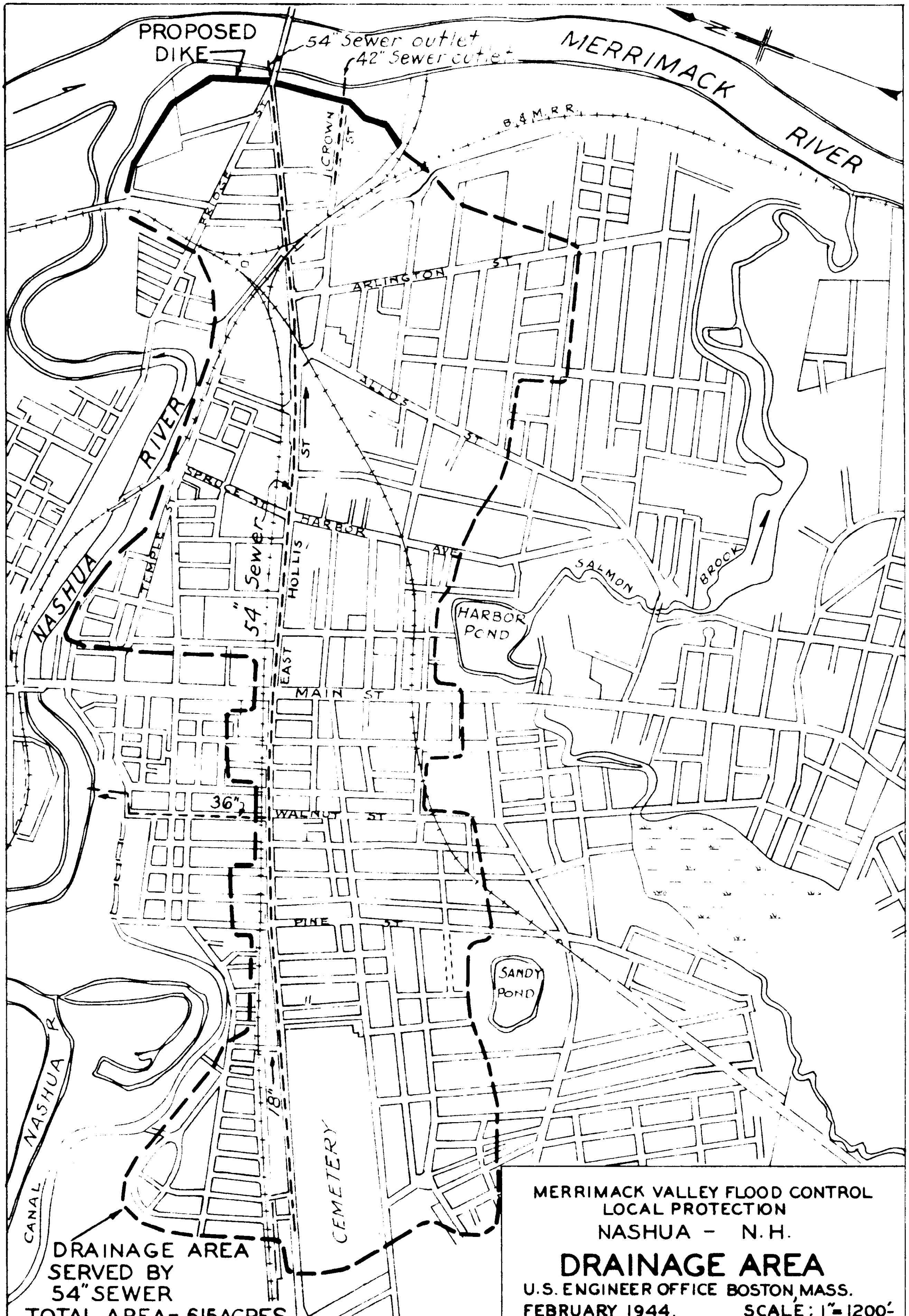
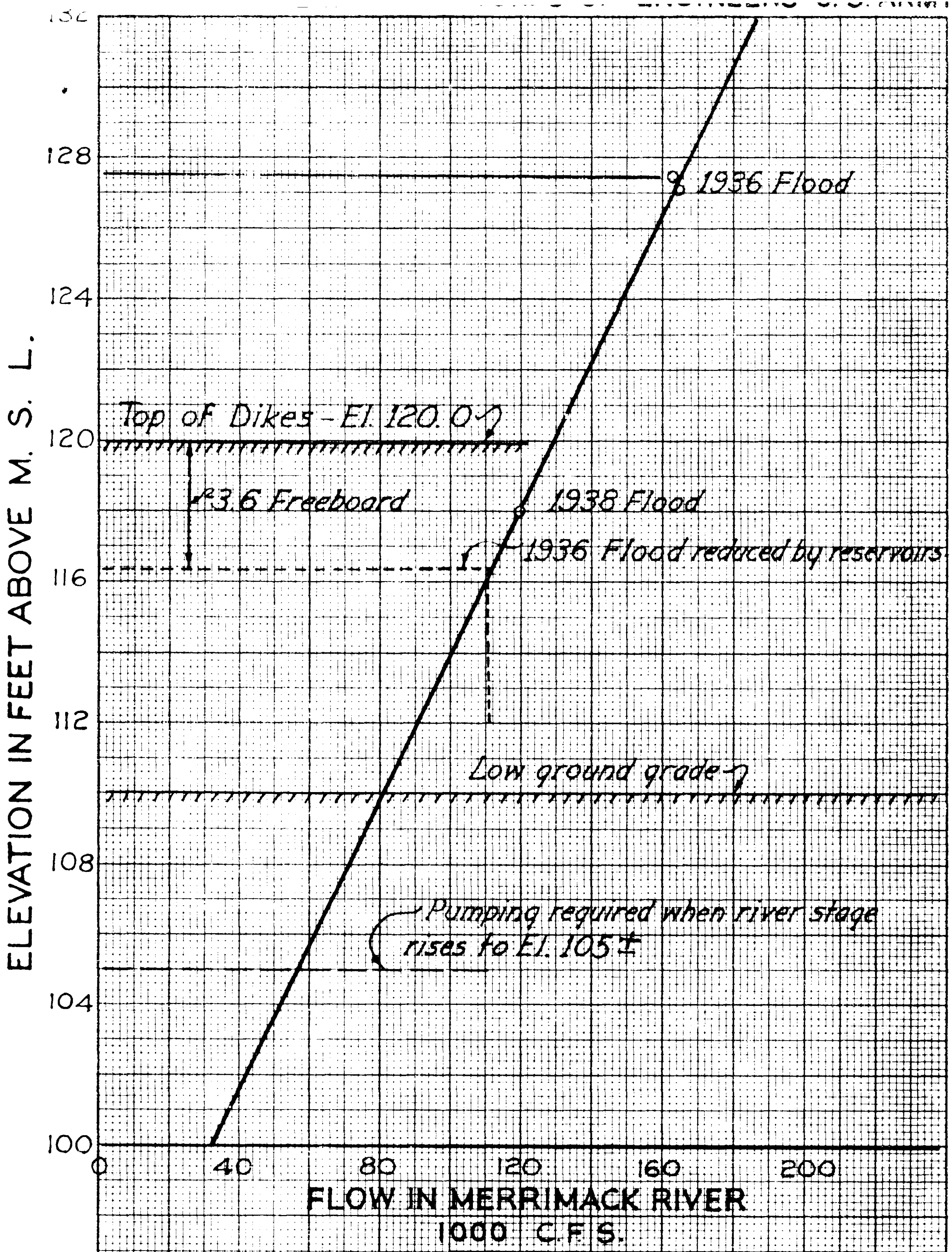
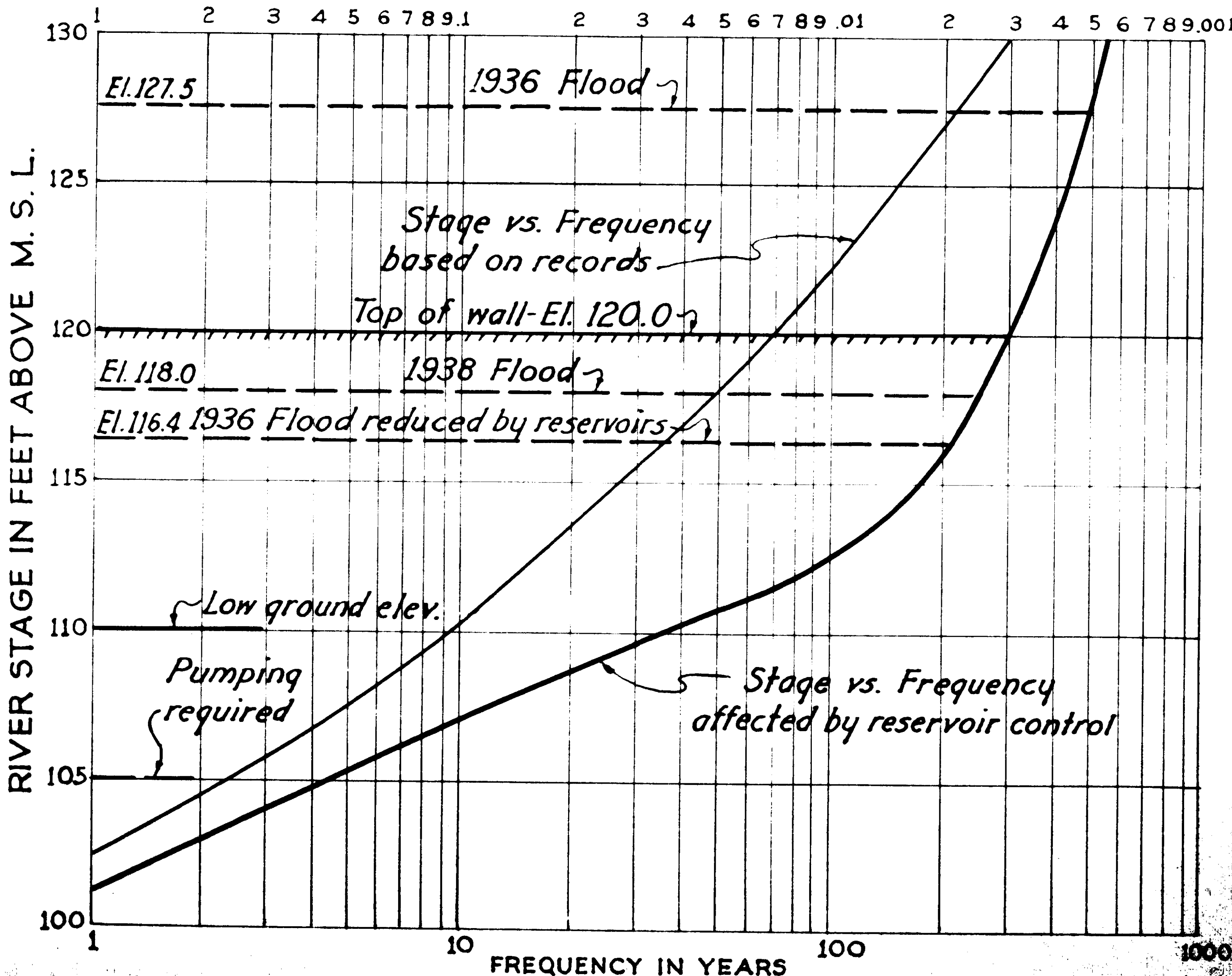

PROPOSED DIKE
54" Sewer outlet
42" Sewer outlet
MERRIMACK RIVER
N
B & M.R.R.
CROWN ST
ARLINGTON ST
NASHUA RIVER
SPRUCE ST
HARBOR AVE
54" Sewer
HOLLIS ST
TEMPLE ST
SALMON BROOK
HARBOR POND
EAST
MAIN ST
36"
WALNUT ST
PINE ST
SANDY POND
NASHUA R
18"
CEMETERY
CANAL
DRAINAGE AREA SERVED BY 54" SEWER
TOTAL AREA= 615ACRES.
MERRIMACK VALLEY FLOOD CONTROL
LOCAL PROTECTION
NASHUA - N.H.
DRAINAGE AREA
U.S. ENGINEER OFFICE BOSTON, MASS.
FEBRUARY 1944.
SCALE: 1"=1200'

PLATE 7



MERRIMACK VALLEY FLOOD CONTROL
NASHUA, N.H.
LOCAL PROTECTION
STAGE DISCHARGE RATING CURVE
U. S. ENGINEER OFFICE, BOSTON, MASS., FEB. '44



MERRIMACK VALLEY FLOOD CONTROL
NASHUA, N.H.
LOCAL PROTECTION
STAGE – FREQUENCY CURVE
U. S. ENGINEER OFFICE, BOSTON, MASS., FEB. '44

PLATE 9